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Vertical Linkage, Tariffs and Welfare in General Equilibrium

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This paper examines the welfare effects of trade liberalization in a general equilibrium model with monopolistically competitive downstream industries and oligopolistic upstream industries. We show that tariff reduction in final goods necessarily raises welfare while tariff reduction in intermediate goods raises welfare if the number of exporting firms is much smaller than the number of non-trading firms. Given recent evidence that exports concentrate on a small fraction of large firms, our results suggest that trade liberalization in both kinds of industries is welfare-improving. We discuss that the general equilibrium setting with no outside numeraire good plays a crucial role.

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1 Introduction

Is trade liberalization beneficial? The answer is affirmative under the condition of perfect competition and constant returns to scale.[1] However, it is too rough to apply the conclusion in the classical trade theory to today's world trade, which involves the following two characteristics. First, only a small fraction of large firms engages in exporting. This fact is firmly established in the rapidly growing literature beginning with Melitz (2003).[2] Freund and Pierola (2015), for example, find that only the top

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1) See, for instance, Feenstra (2016, Chapter 7).

2) Melitz and Redding (2014) and Feenstra (2016) provide a detailed review of the literature on heterogeneous firms and trade.

firms account for 30% of aggregate exports on average across 32 countries. By overviewing the more recent literature, Head and Spencer (2017, Section 4) and Bernard et al. (2018, Section 4) commonly conclude that the above fact is robust across a wide range of countries. The second characteristic of modern world trade is the substantial share of intermediate goods trade. Focusing on the OECD countries, Miroudot et al. (2009) report that intermediate inputs represent 56% of goods trade and 73% of services trade. OECD (2013) also emphasizes the role of intermediate goods trade in a context of Global Value Chains (GVCs).[3] In addition, McCorriston and Sheldon (2011) and Hwang et al. (2017) also point out the importance of intermediate goods trade in a context of tariff escalation and effective protection.

Having these two features on world trade in mind, this paper shows some unexplored implications on the effects of trade liberalization in vertically related markets. While a large literature has examined trade policy with vertically linked markets, this paper differs from it in the following respects. First, we stress the general equilibrium effects on welfare by employing a nested Cobb-Douglas-CES preference without the assumption of outside numeraire good.[4] Since there is no outside good that fixes the wage rate in our model, the effect of tariff reduction on the wage rate is crucial for the welfare effect. Recently, Felbermayr and Jung (2012), Takatsuka and Zeng (2016) and Demidova (2017) demonstrate that dropping the outside good leads to a drastic change in welfare effects of trade liberalization in monopolistic competition. Our paper is also along this direction of research. Second, we assume a vertical structure in which the downstream

3) Antras and Chor (2018) overview the existing measures of the degree of GVCs.

4) The nested Cobb-Douglas-CES preference refers to a utility function with the upper-tier function being Cobb-Douglas and the lower-tier function being CES. Antras (2003), Atkeson and Burstein (2007), Hottman et al. (2016) and Bernard et al. (2017) utilize this preference.

(final goods) sector is monopolistically competitive and the upstream (intermediate goods) sector is oligopolistic.[5)] Third, we allow both the final and intermediate goods to be traded and non-traded.

In the above-mentioned model, we prove two main results. First, trade liberalization in the downstream industry necessarily raises welfare. Second, trade liberalization in the upstream industry raises welfare if the number of exporting firms is much smaller than the number of non-trading firms. Relating the latter result to the empirical evidence noted earlier, this sufficient condition is safely satisfied, and hence trade liberalization in both kinds of industries is welfare-improving. That is, even if the two important elements in today's world trade above are allowed, trade liberalization in both final and intermediate goods should be promoted. Our finding hopefully provides a theoretical rationale for non-discriminatory trade liberalization at the global level.

Someone may wonder if our specification of market structure is special, but it is utilized in previous works. To our knowledge, Kuhn and Vives (1999) are the first to model a vertically related market with a monopolistically competitive downstream industry and a monopolistic upstream industry. They examine the effect of vertical integration, and derive the sufficient condition for Pareto-improving vertical integration. Behrens et al. (2009) develop a New Economic Geography model in which the downstream industry is monopolistically competitive and the downstream industry (transportation industry in their context) is a Cournot oligopoly. In this model, they show that an exogenous increase in the number of transportation firms raises (resp. lowers) consumer surplus if dispersion (resp. agglomeration) occurs. Furthermore, by incorporating a Cournot

5) We sometimes call the good produced in the upstream industry an 'intermediate good,' but our modeling of the upstream industry can apply to transportation services and natural resources.

oligopolistic shipping industry into the monopolistically competitive model, Hummels et al. (2009) empirically find that shipping firms reduce prices by 1-2% for every 1% reduction in tariffs on the final goods. Although we use a similar model, our focus is on the welfare effects of tariff reduction in the downstream and downstream industries, which are not addressed in the above papers.

Apart from the above literature, this paper is closely related to the literature that studies trade policy and trade liberalization in vertically related markets. Spencer and Jones (1991, 1992), Ishikawa and Lee (1997) and Ishikawa and Spencer (1999) investigate strategic trade policies when both downstream and upstream industries are oligopolistic. Venables (1996) and Amiti (2000, 2005), in contrast, assume that both kinds of industries are monopolistically competitive, and examine the effect of lower trade cost on the agglomeration.

This paper is organized as follows. Section 2 presents a model. Section 3 addresses the effect of trade liberalization on the wage rate, which plays a crucial role for welfare effect. The welfare effect of trade liberalization is considered in Section 4. Section 5 concludes.

2 Model

We assume two identical countries (Home and Foreign), but we focus on Home only because Foreign is a mirror image of Home. There are a downstream (final goods) and an upstream (intermediate goods) industries. Drawing on Kuhn and Vives (1999), Behrens, Gaigne and Thisse (2009), monopolistic competition prevails in the downstream industry while the upstream industry is oligopolized in Cournot competition. The goods markets are segmented. And, we allow both final and intermediate goods to be traded and non-traded. The import of final and intermediate goods is subject to an ad valorem tariff $t \geq 0$ and $\tau \geq 0$, respectively. Since the model has a vertical structure, we derive the demand of final goods, characterize the equilibrium in the downstream and upstream industries, respectively, and then derive the general equilibrium.

2.1 Consumer Behavior

The utility function of a representative consumer in Home is assumed to be

$$U = \ln\left(X^{\alpha}\overline{X}^{1-\alpha}\right) \tag{1}$$

$$X \equiv \left(\int_0^m x_i^{\frac{\sigma-1}{\sigma}} di + \int_0^m x_i^{*\frac{\sigma-1}{\sigma}} di\right)^{\frac{\sigma}{\sigma-1}}, \quad \overline{X} \equiv \left(\int_0^{\overline{m}} \overline{x}_i^{\frac{\sigma-1}{\sigma}} di\right)^{\frac{\sigma}{\sigma-1}}, \quad \sigma > 1$$

where U is utility, x_i and x_i^* are consumption of Home and Foreign goods that are traded, and m is the mass of varieties of differentiated products. The upper-bar attached to variables stands for the non-traded good. Thus, X and $\overline{X}$ denote the quantity index of traded and non-traded goods, respectively. The consumer chooses consumption to maximize (1) under the budget constraint:

$$\int_0^m p_i x_i di + \int_0^m p_i^* x_i^* di + \int_0^{\overline{m}} \overline{p}_i \overline{x}_i di \leq I,$$

where I is national income.

In the existing literature, it is assumed that a perfectly competitive numeraire good is produced with a unit input coefficient. Under this assumption, the factor price (wage rate in our model) is fixed to unity, and not affected by policy changes. However, a few papers recently show that the welfare effect of trade liberalization is reversed if this assumption is relaxed.[6)] Reflecting this fact, we also assume no outside good whose price is unity. Instead, we choose utility as a numeraire so that marginal utility of income (Langrangean multiplier associated with the budget constraint) is

6) See Felbermayr and Jung (2012), Takatsuka and Zeng (2016) and Demidova (2017). These papers assume that the wage rate of Foreign labor is normalized to one.

unity.[7] The justification for this numeraire choice is provided as follows. In the present general equilibrium model, marginal utility of income depends on the outputs and prices of imperfectly competitive firms. Therefore, if imperfectly competitive firms were quite rational, they take into account the above dependence in choosing the profit-maximizing output/price.[8] As Neary (2003, 2016) notes, this leads to much difficulty, e.g. discontinuity of reaction functions and non-existence of equilibrium. In order to overcome such difficulty, it is useful to normalize marginal utility of income to one, implying that any firm takes it as given.

Under the above price normalization, the demand function of final goods is obtained as

$$x_i = \frac{\alpha p_i^{-\sigma}}{P^{1-\sigma}}, \quad x_i^* = \frac{\alpha p_i^{*-\sigma}}{P^{1-\sigma}}, \quad \overline{x}_i = \frac{(1-\alpha)\overline{p}_i^{-\sigma}}{\overline{P}^{1-\sigma}}, \tag{2}$$

where P and $\overline{P}$ are the price index of traded and non-traded varieties, respectively:

$$P \equiv \left(\int_0^m p_i^{1-\sigma} di + \int_0^m p_i^{*1-\sigma} di \right)^{\frac{1}{1-\sigma}}, \quad \overline{P} \equiv \left(\int_0^{\overline{m}} \overline{p}_i^{1-\sigma} di \right)^{\frac{1}{1-\sigma}}. \tag{3}$$

Then, utilizing (2), the following relationship between the quantity and price indices holds.

$$X = \frac{\alpha}{P}, \quad \overline{X} = \frac{1-\alpha}{\overline{P}}. \tag{4}$$

This relationship will be used in addressing the welfare effect of trade liberalization later.

2.2 Downstream Industry

Having obtained the demand function of final goods, we turn to the equilibrium in the downstream industry. We assume that final goods firms use traded and non-traded intermediate goods, and total cost of

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7) This choice of numeraire is familiar in the literature of 'General Oligopolistic Equilibrium' (GOLE) model pioneered by Neary (2003, 2016).

8) This is sometimes called a Ford Effect.

a representative traded final good is given by $Q(x_i + x_i^* + f)$, where $Q \equiv q^{\beta}\overline{q}^{1-\beta}, \beta \in (0,1)$, q and $\overline{q}$ are the price of traded and non-traded intermediate inputs, respectively, and f is a positive constant.[9] Since the downstream industry is characterized by monopolistic competition of the Dixit-Stiglitz (1977) type, the price of final goods is determined according to markup pricing:

$$p = \frac{\sigma Q}{\sigma - 1}, \quad p^* = \frac{(1+t)\sigma Q}{\sigma - 1}, \quad \overline{p} = \frac{\sigma Q}{\sigma - 1}. \tag{5}$$

Substituting (5) into the zero profit condition yields total output:

$$x_i + x_i^* = (\sigma - 1)f, \quad \overline{x}_i = (\sigma - 1)f. \tag{6}$$

The next task is to determine the equilibrium mass of differentiated goods.[10] To do it, let us consider the market-clearing conditions of final goods:

$$\begin{aligned} x + x^* &= \frac{\alpha\left[1 + (1+t)^{-\sigma}\right]}{m\left[1 + (1+t)^{1-\sigma}\right]p} = \frac{\alpha\left[1 + (1+t)^{-\sigma}\right](\sigma - 1)}{m\left[1 + (1+t)^{1-\sigma}\right]\sigma Q} = (\sigma - 1)f \\ \overline{x} &= \frac{1-\alpha}{\overline{m}\overline{p}} = \frac{(1-\alpha)(\sigma - 1)}{\overline{m}\sigma Q} = (\sigma - 1)f, \end{aligned}$$

where the second equality in each line uses (5). Because m and $\overline{m}$ are determined in a way to satisfy these market-clearing conditions, solving them for m and $\overline{m}$, we have

$$m = \frac{\alpha\left[1 + (1+t)^{-\sigma}\right]}{\sigma\left[1 + (1+t)^{1-\sigma}\right]Qf}, \quad \overline{m} = \frac{1-\alpha}{\sigma Q f}. \tag{7}$$

This completes the description of the downstream industry. The next subsection derives the price of the intermediate goods q and $\overline{q}$.

2.3 Upstream Industry

This subsection derives the equilibrium in the upstream industry. Applying Shephard's Lemma to the cost function of individual final goods firms $q^{\beta}\overline{q}^{1-\beta}(x + x^* + f)$, and aggregating the resulting expressions, the

9) This specification of production cost follows Francois (1992, 1994).

10) In what follows, subscript i is suppressed because all the traded and non-traded firms are symmetric.

market-clearing conditions of traded and non-traded intermediate goods become

$$\beta q^{\beta-1}\overline{q}^{1-\beta}\left[m(x+x^*+f)+\overline{m}\left(\overline{x}+f\right)\right] = \sum_{j=1}^{n} y_j + \sum_{j=1}^{n} y_j^*$$
$$(1-\beta)q^{\beta}\overline{q}^{-\beta}\left[m(x+x^*+f)+\overline{m}\left(\overline{x}+f\right)\right] = \sum_{j=1}^{\overline{n}} \overline{y}_j,$$

where y_j and y_j^* are output of a traded intermediate good produced by a Home and a Foreign firms, respectively, and $\overline{y}_j$ is output of a non-traded intermediate goods. The left-hand sides of these equations are aggregate demand of intermediate goods, and the right-hand sides are aggregate supply. Solving these equations for q and $\overline{q}$, the inverse demand functions are given by[11)]

$$q = \frac{\beta M}{\sum_{j=1}^{n} y_j + \sum_{j=1}^{n} y_j^*}, \quad \overline{q} = \frac{(1-\beta)M}{\sum_{j=1}^{\overline{n}} \overline{y}_j} \tag{8}$$
$$M \equiv \frac{\alpha\left[1+(1+t)^{-\sigma}\right]}{1+(1+t)^{1-\sigma}} + 1 - \alpha.$$

The provision of intermediate goods is under the condition of a Cournot oligopoly with a perfect substitute and market segmentation. Each firm employs labor as a sole input, and has the same input coefficient $c \geq 0$. Then, firms choose output such that the following first-order conditions are satisfied.

$$\frac{\beta[(n-1)y+ny^*]M}{n^2(y+y^*)^2} = wc, \quad \frac{\beta[ny+(n-1)y^*]M}{(1+\tau)n^2(y+y^*)^2} = wc$$
$$\frac{(1-\beta)\left(\overline{n}-1\right)M}{\overline{n}^2\overline{y}} = wc,$$

where the left-hand sides are marginal revenue, and the right-hand sides

11) From (6) and (7), we have

$$m(x+x^*+f)+\overline{m}\left(\overline{x}+f\right) = \frac{M}{q^{\beta}\overline{q}^{1-\beta}}.$$

are marginal cost, respectively. Note here that the Foreign firm has to incur an import tariff τ in exporting. From these equations, the industry output of traded and non-traded intermediate goods is

$$n(y+y^*) = \frac{\beta(2n-1)M}{(2+\tau)nwc}, \quad \overline{ny} = \frac{(1-\beta)(\overline{n}-1)M}{\overline{n}wc}. \tag{9}$$

Substituting (9) into the inverse demand functions (8) yields the equilibrium price of intermediate goods that is a function of the wage rate w.

2.4 General Equilibrium

We now close the model by introducing the labor market-clearing condition. Making use of (9), the labor market-clearing condition is given by

$$\begin{aligned} L &= nc(y+y^*) + \overline{n}c\overline{y} = \frac{\beta(2n-1)M}{(2+\tau)nw} + \frac{(1-\beta)(\overline{n}-1)M}{\overline{n}w} = \frac{MN}{w} \\ N &\equiv \frac{\beta(2n-1)}{(2+\tau)n} + \frac{(1-\beta)(\overline{n}-1)}{\overline{n}}, \end{aligned}$$

where L is the labor endowment, and the right-hand side is aggregate demand of labor. Solving this equation for w, the equilibrium wage rate is derived as

$$w = \frac{MN}{L}. \tag{10}$$

Once w is determined in (10), all the other endogenous variables are expressed by a function of policy parameters t and τ. In the subsequent sections, we examine how reduction in t and τ affects the endogenous variables.

3 Wage Effects of Trade Liberalization

Although our main interest is in the welfare effect of trade liberalization, this section examines its effect on the wage rate and goods prices as an auxiliary step to welfare analysis. In the present model, a change in tariffs affects the goods prices and welfare through two channels. The first channel is a direct effect through which tariff reduction lowers the price of final and intermediate goods. The second channel is an indirect effect coming from a change in the wage rate (10). Because the overall effect is determined by the interplay of these two sub-effects, we should carefully examine the effect of tariff reduction on the wage rate. This is formally stated as follows.

Proposition 1. *Trade liberalization in final goods raises the wage rate under the sufficient condition*

$$1-(\sigma-1)t+(1+t)^{1-\sigma}>0. \tag{11}$$

And, trade liberalization in intermediate goods necessarily raises the wage rate.

Proof. Recall that M and N in (10) are defined by

$$\begin{aligned} M &\equiv \frac{\alpha\left[1+(1+t)^{-\sigma}\right]}{1+(1+t)^{1-\sigma}}+1-\alpha \\ N &\equiv \frac{\beta(2n-1)}{(2+\tau)n}+\frac{(1-\beta)\left(\overline{n}-1\right)}{\overline{n}}. \end{aligned}$$

Given these definitions of M and N, differentiating (10) with respect to t and τ, we have

$$\begin{aligned} \frac{\partial w}{\partial t} &= \frac{N}{L}\cdot\frac{\partial M}{\partial t}=-\frac{N}{L}\cdot\frac{\alpha(1+t)^{-1-\sigma}\left[1-(\sigma-1)t+(1+t)^{1-\sigma}\right]}{\left[1+(1+t)^{1-\sigma}\right]^2} \\ \frac{\partial w}{\partial \tau} &= \frac{M}{L}\cdot\frac{\partial N}{\partial \tau}=-\frac{M}{L}\cdot\frac{(2n-1)\beta}{(2+\tau)^2 n}<0. \end{aligned}$$

Therefore, we have $\partial w/\partial t<0$, i.e. lower t raises the wage rate if t and σ satisfy (11). In contrast, it unambiguously holds that the wage rate rises as τ falls. ||

The intuitions underlying this result are explained as follows. As the tariff on the final goods import is lower, exporting firms of final goods charge a lower price. This lowers the price index of traded final goods P. This reduction in P *decreases* aggregate demand for domestically produced final goods whereas it *increases* aggregate demand for imported final goods.[12)] Due to these competing effects on aggregate demand for domestic and foreign final goods, it is ambiguous whether tariff reduction in final goods raises the equilibrium mass of traded goods m. Consequently, the effect on the equilibrium wage is also ambiguous.

Figure 1

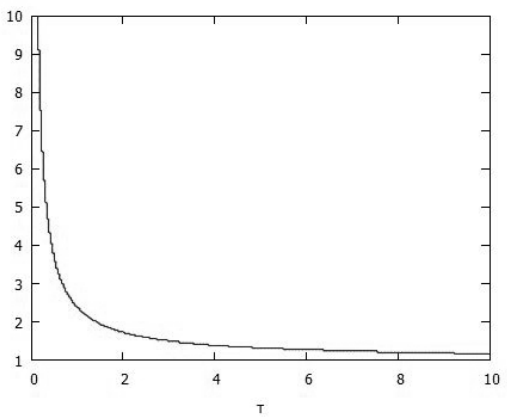

Figure 1 illustrates the area in which $\partial w/\partial t$ is positive or negative in the $t-\sigma$ plane. In the figure, the downward-sloping curve gives a combination of t and σ such that $1-(\sigma-1)t+(1+t)^{1-\sigma}=0$. This figure tells that $\partial w/\partial t<0$ (resp. $\partial w/\partial t>0$) if the pair (t,σ) is below (resp. above) this curve. In words, if either or both of σ and t is sufficiently small, the decrease in aggregate demand for domestically produced goods is dominated by

12) This is confirmed by invoking that demand for final goods is given by

$$x_i=\frac{\alpha p_i^{-\sigma}}{P^{1-\sigma}},\quad x_i^*=\frac{\alpha p_i^{*-\sigma}}{P^{1-\sigma}},\quad \overline{x}_i=\frac{(1-\alpha)\overline{p}_i^{-\sigma}}{\overline{P}^{1-\sigma}},$$

and x_i (resp. x_i^*) is increasing (resp. decreasing) in P. Note also that aggregate demand for non-traded final goods is unchanged by tariff reduction.

the increase in aggregate demand for imported goods, leading to a larger variety of traded final goods and a higher wage rate.

In contrast, the effect of tariff reduction in intermediate goods is simple. From (9), reduced tariffs in intermediate goods increase total output of the traded intermediate goods. Since this induces aggregate labor demand in the whole economy to rise, the market-clearing wage also rises.

In most of the existing literature, no policy change affects the wage rate because it is fixed to unity by assuming that one unit of labor produces one unit of a perfectly competitive numeraire good. In monopolistic competition models without the upstream industry, Felbermeyr and Jung (2012), Takatsuka and Zeng (2016) and Demidova (2017) show that the welfare effect of trade liberalization is reversed if the assumption of outside numeraire good is relaxed.[13] Similarly, Proposition 1 also suggests that 'the outside good is not innocuous to evaluate trade policies.' (Takatsuka and Zeng, 2016, p. 66)

4 Welfare Effects of Trade Liberalization

In the last section, tariff reductions are shown to have a significant impact on the equilibrium wage rate. Based on the argument therein, we now turn to addressing the welfare effects of trade liberalization. Substituting (2) into the utility function yields indirect utility W:

$$\begin{aligned} W &= \ln\left[\left(\frac{\alpha}{P}\right)^{\alpha}\left(\frac{1-\alpha}{\overline{P}}\right)^{1-\alpha}\right] \\ &= \ln\left[\alpha^{\alpha}(1-\alpha)^{1-\alpha}\right] - \ln\left(P^{\alpha}\overline{P}^{1-\alpha}\right). \end{aligned}$$

This expression allows us to know that W negatively depends on $P^{\alpha}\overline{P}^{1-\alpha}$, which has the form

13) Felbermeyr and Jung (2012) and Takatsuka and Zeng (2016) assume a CES utility function whereas Demidova (2017) assumes a quadratic utility function.

$$
\begin{aligned}
P^{\alpha}\overline{P}^{1-\alpha} &= \left\{m\left[1+(1+t)^{1-\sigma}\right]p^{1-\sigma}\right\}^{\frac{\alpha}{1-\sigma}}\left(\overline{m}\overline{p}^{1-\sigma}\right)^{\frac{1-\alpha}{1-\sigma}} \\
&= \left\{m\left[1+(1+t)^{1-\sigma}\right]\right\}^{\frac{\alpha}{1-\sigma}}\overline{m}^{\frac{1-\alpha}{1-\sigma}}p.
\end{aligned}
$$

Invoking that p, m and $\overline{m}$ are given by (5) and (7), respectively, this expression is further rewritten as

$$
P^{\alpha}\overline{P}^{1-\alpha} = \left[\alpha^{\alpha}(1-\alpha)^{1-\alpha}\right]^{\frac{1}{1-\sigma}}(\sigma f)^{\frac{1}{\sigma-1}}\frac{\sigma}{\sigma-1}Q^{\frac{\sigma}{\sigma-1}}\left[1+(1+t)^{-\sigma}\right]^{\frac{\alpha}{1-\sigma}}.
$$

Substituting this into W, welfare is obtained by a function of two tariffs as follows.

$$
\begin{aligned}
W \quad &= \ln\left[\alpha^{\alpha}(1-\alpha)^{1-\alpha}\right] - \ln\left[\alpha^{\frac{\alpha}{1-\sigma}}(1-\alpha)^{\frac{1-\alpha}{1-\sigma}}(\sigma f)^{\frac{1}{\sigma-1}}\frac{\sigma}{\sigma-1}\right] + F(t,\tau) \\
F(t,\tau) &\equiv -\frac{1}{\sigma-1}\left\{\sigma\ln Q - \alpha\ln\left[1+(1+t)^{-\sigma}\right]\right\}, \qquad (12)
\end{aligned}
$$

where Q is given by

$$
\begin{aligned}
Q = q^{\beta}\overline{q}^{1-\beta} &= \left[\frac{\beta M}{n(y+y^{*})}\right]^{\beta}\left[\frac{(1-\beta)M}{\overline{n}\overline{y}}\right]^{1-\beta} \\
&= \left[\frac{(2+\tau)nc}{2n-1}\frac{MN}{L}\right]^{\beta}\left(\frac{\overline{n}c}{\overline{n}-1}\frac{MN}{L}\right)^{1-\beta} \\
&= \left[\frac{(2+\tau)n}{2n-1}\right]^{\beta}\left(\frac{\overline{n}}{\overline{n}-1}\right)^{1-\beta}\frac{cMN}{L} \\
&= \frac{\overline{n}(2n-1)\beta + n\left(\overline{n}-1\right)(1-\beta)(2+\tau)}{L}\left[\frac{c}{\overline{n}(2n-1)}\right]^{\beta}\left[\frac{c}{n\left(\overline{n}-1\right)(2+\tau)}\right]^{1-\beta} \\
&\quad \times\left\{\frac{\alpha\left[1+(1+t)^{-\sigma}\right]}{1+(1+t)^{1-\sigma}} + 1 - \alpha\right\},
\end{aligned}
$$

by utilizing $w = MN/L$ and the definition of M and N. This completes the preparation for welfare analysis of trade liberalization.

The welfare effect of trade liberalization in final goods can be stated as follows.

Proposition 2. *Trade liberalization in final goods necessarily raises welfare.*

Proof. Differentiating (12) with respect to t and making lengthy manipulations, we have

$$\frac{dF(t,\tau)}{dt} = -\frac{\alpha\sigma t A}{(\sigma-1)(1+t)^{1+\sigma}\left[1+(1+t)^{-\sigma}\right]\left[1+(1+t)^{1-\sigma}\right]B} < 0$$

$$A \equiv (1-\alpha)(1+t)^{-\sigma}\left[1+(1+t)^{1-\sigma}\right] + (\sigma-1)\left[1+(1+t)^{-\sigma}\right] > 0$$

$$B \equiv \alpha\left[1+(1+t)^{-\sigma}\right] + (1-\alpha)\left[1+(1+t)^{1-\sigma}\right] > 0.$$

Therefore, it holds that $F(\cdot)$ is increasing in t, implying that welfare becomes higher as t is lower. ||

As shown in Proposition 1, it is unclear whether the wage rate rises as the tariff on the imported final goods is reduced. Because the other endogenous variables, e.g. prices of final and intermediate goods and the mass of final goods, depend on the wage rate, it is also unclear whether reducing t increases or decreases these variables. However, Proposition 2 tells that welfare unambiguously rises as t falls. This is explained as follows.

When t is reduced, both the price of imported final goods and the price index of traded final goods decrease, which tends to raise welfare. In addition to this direct effect, there is an indirect effect that stems from the wage adjustment. In the case in which trade liberalization lowers the wage rate, the marginal cost and price of both final goods and intermediate goods also decline. Therefore, not only the direct effect but also the indirect effect serves to raise welfare.

However, as is made clear in Proposition 1, the wage rate rises if condition (11) is satisfied. Then, while the direct effect tends to raise welfare, the indirect effect tends to lower welfare. What is important is that Proposition 2 claims that even in this case the direct outweighs the indirect effect, and hence trade liberalization in final goods definitely improves welfare.

Finally, we turn to the welfare effect of trade liberalization in intermediate goods. This is formally stated as follows.

Proposition 3. *Trade liberalization in intermediate goods raises welfare if*

$$\tau > \frac{2n - \overline{n}}{n\left(\overline{n} - 1\right)} \tag{13}$$

Proof. Differentiating W in (11) with respect to τ yields

$$\frac{dW}{d\tau} = -\frac{\sigma\beta(1-\beta)\left[n\left(\overline{n}-1\right)\tau + \overline{n} - 2n\right]}{(2+\tau)\left[\overline{n}(2n-1)\beta + n\left(\overline{n}-1\right)(1-\beta)(2+\tau)\right]}.$$

Therefore, we have $dW/d\tau < 0$, i.e. tariff reduction of intermediate goods raises welfare, under the sufficient condition (13). ||

As in the case of trade liberalization in final goods, we decompose the overall effect into a direct effect and an indirect effect. On the one hand, it follows from (9) that total output of traded intermediate goods increases, that is, there is a pro-competitive effect, when the tariff on the imported intermediate goods is reduced. This lowers both the marginal cost and price of all final goods, and hence tends to raise welfare. On the other hand, trade liberalization in intermediate goods raises the equilibrium wage rate. This wage appreciation subsequently increases the marginal cost and price of intermediate goods, which further raises the marginal cost and price of final goods. This tends to have a negative welfare effect. The above proposition tells that if the initial tariff is sufficiently high, the former effect is stronger than the latter effect, leading to higher welfare.

What is worth stressing is that condition (13) is necessarily satisfied if the number of non-trading firms is much larger than the number of exporting firms such that $\overline{n} > 2n$. In other words, under this condition, trade liberalization in intermediate goods is necessarily beneficial. Relating this finding to the recently growing evidence that only a small fraction of firms exports, tariff reduction in intermediate goods is safely welfare-enhancing. Combining Proposition 3 with Proposition 2, we can conclude that trade liberalization in final and intermediate goods raises welfare under the plausible set of parameters.

5 Conclusion

We have developed a two-country general equilibrium model in which a monopolistically competitive downstream (final goods) industry and an oligopolistic upstream (intermediate goods) industry interact. If the import tariff is reduced in these industries, the wage rate is significantly affected, and hence the welfare effect of trade liberalization is shown to be more complicated than in the existing literature with perfectly elastic labor supply. Concretely, tariff reduction in final goods unambiguously raises welfare while its effect on the wage rate is generally unclear. On the other hand, tariff reduction in intermediate goods raises welfare if the number of exporting firms is sufficiently smaller than the number of non-trading firms. Relating this result to the recent evidence that only a small fraction of firms exports, trade liberalization in both final and intermediate goods is welfare-enhancing. Furthermore, the above results suggest that welfare is more likely to improve by simultaneously liberalizing trade in both kinds of goods even if trade liberalization in intermediate goods alone is welfare-reducing. To summarize, our overall evaluation for trade liberalization is positive even though the above type of vertical linkage is taken into account.

Of course, there are admittedly a number of limitations in this paper. First, we assume a special type of a vertically related market in which the downstream industry is monopolistically competitive and the upstream industry is oligopolistic. As noted in Introduction, the welfare effect of trade liberalization has not been analyzed in this kind of vertical structure although its effect on the agglomeration pattern is addressed in the New Economic Geography. In this sense, this paper hopefully contributes to literature, but there are many alternative types of vertical structure. It is an important task to examine whether our results are valid in other types of vertically related markets. Second, we have assumed the Cobb-Douglas-CES utility function, i.e. the upper-tier function is Cobb-Douglas and the lower-tier function is CES. This remarkably facilitates analysis and thus is employed in previous works as well, e.g. Antras (2003), Atkeson and Burstein (2007), Hottman et al. (2015) and Bernard et al. (2018), but the assumption of unitary elasticity of substitution between traded and non-traded final goods is undoubtedly severe. It is also important to relax this assumption and utilize a nested CES model, which is increasingly popular in the recent quantitative literature.[14)]

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